

Design methodologies for M-health innovations: a content analysis

Shah Jahan Miah

Information Systems Discipline
College of Business, Victoria University
Melbourne, Australia
Email: shah.miah@vu.edu.au

John Gammack

College of Technological Innovation
Zayed University, Abu Dhabi, U.A.E.
Email: John.Gammack@zu.ac.ae

Najmul Hasan

MRC Bangladesh Ltd
Dhaka, Bangladesh
Email: rajibrj43@gmail.com

Md. Rakibul Hoque

Faculty of Business Studies, University of Dhaka
Dhaka, Bangladesh
Email: rakibulmisdu@gmail.com

Abstract

Whilst researchers and professionals recognize that M-health offers great opportunities, most existing work has comprised individual project-based developments in specialised areas. Existing review papers generally utilise medical literature and categories: none investigates M-health from an IS design point of view. Identifying application areas, design issues and IS research techniques will demonstrate models, issues, approaches and gaps to inform future research. A comprehensive analysis of up to date literature from this viewpoint is valuable, both for theoretical progression and for guiding real-world innovative developments.

Drawing from key IS and multidisciplinary journals we analyse recent (2010-2016) articles concerning M-health application developments and their associated design or development issues. We identify eight application categories, ten design issues (security, privacy, literacy, accessibility, acceptability, reliability, usability, confidentiality, integrity and knowledge sharing) and the stakeholders and development techniques involved. The analysis suggests M-health is an emerging field to which design science is particularly appropriate.

Keywords mobile-based Innovations, M-health, design science, content analysis, information systems design methodologies

1 Introduction

Research on healthcare applications for mobile devices (M-health) has gained increasing attention over the past decade. M-health is broadly defined as a service or mobile application for providing healthcare support to anyone, anytime, and anywhere (Varshney, 2014). M-health aims to provide health professionals, patients, clinicians and other relevant users with information support services to manage, disseminate, collect, administer, control and monitor healthcare information and improve health service delivery and quality of care support. The service eliminates geographical and temporal constraints while enhancing the coverage, quality, cost savings and other user provisions of healthcare (Nhavoto and Grönlund, 2014; Varshney, 2014).

Various innovative IS techniques in M-health have been proposed and many forms of M-health applications have been developed as fully functional system solutions. Currently M-health offers not only access to applications through mobile devices, but also provides for associating data from various sensors, automatic trackers and relevant stakeholders. Through Internet enabled wireless networks and/or other forms of connectivity such as Bluetooth the M-health innovations allow acquisition, monitoring, forecasting, sharing and control of various health conditions. Such provision is designed for healthcare personnel and patients with various needs to make decisions regarding treatments and care support, and administration requirements for developing anytime-anywhere service support. Illustrative examples include: M-health systems for remote patient monitoring (Baig et al. 2015), disease prevention and wellbeing (Walton and Derenzi, 2009), knowledge exchange (Pulijala et al. 2015) and medication management (Lee et al. 2014).

As M-health research has matured it has gained increasing attention by information systems (IS) researchers and healthcare system professionals alike. This is due to its practical relevance to patients, healthcare professionals, application developers, service providers and other agents and to the ubiquity of mobile devices and apps. Although the benefits are clear for target agents/groups such as patients and elderly (e.g. for receiving emergency care, and assistance to manage their daily activities in independent living), health professionals (e.g. improving decision making and providing care support to patients), and healthcare organisations or service providers (e.g. for expanding healthcare coverage, providing suitable healthcare in emergencies, and offering awareness on prevention), M-health as a distinct area of IS research has not been previously assessed and conceptualised. Although new research designs have begun to emerge, much of the literature describes individual, project-based application developments which do not offer generalised knowledge contributions, mostly being clinical trials or pilot studies (Fiordelli et al. 2013). Previous reviews of the M-health literature have also typically used top-down categorisations from the medical literature to identify research directions for specific areas of health, and their focus is largely that of medical journals. From the viewpoint of IS, understanding related to the solution themes, the development methods of M-health application and the associated design issues are poorly developed and lacking a theoretical framework. Although emerging as an “autonomous field of study” (Fiordelli et al. 2013), studies in the area of M-health are rarely discussed in terms of the concerns and opportunities within the realm of IS design research.

The typical emphasis of the existing literature review is instrumental: focusing on emerging directions in M-health associated with medical or social categories. The review by Jennings and Gagliani (2013) for example selected only articles related to developing countries, and whose findings concerned gender dynamics. Kallander et al (2013) used predefined M-health themes from the literature to assess how low-middle income countries were approaching the intersection of mobile technology and public health and identified the key challenge of moving from “pilot projects to national scalable programs”.

Although IT and apps are centrally involved, the reviews rarely consider IS issues. Indeed this is an explicit delimitation of the otherwise comprehensive review by Fiordelli et al. (2013) who excluded technology-oriented databases in favour of medical and socially focused sources of articles. Fiordelli et al. (2013) reviewed the decade of M-health research from 2002-12 to assess the impact of mobile phones, describing the field's monotonic and at times exponential growth and categorising articles by medical conditions, usually chronic. They acknowledged they had not considered articles from technology databases, but noted the numerous health apps available on app stores, together with the lack of systematic research on these. More recent research by Silva et al. (2015) aimed to identify M-health potential and challenges, and focused on classifying the 37 most significant apps proposed by industry by therapy area. These were drawn from the iTunes store, and they cite evidence that the US store alone had more than 40000 healthcare apps as of 2013, whilst Varshney (2014) claims there are over 100000 M-health apps available across various devices. Payne et al's. (2015) literature review identified 24 articles on mobile apps for M-health behaviour interventions, but these were found to be mainly pilot or feasibility studies. Although review articles of M-health apps are beginning to emerge,

(e.g. Schnall and Iribarren, 2015) these also tend to have outcomes relevant to specialised medical practitioner audiences. Despite several apps being available, both of these recent articles conclude that functionality is lacking and that there is a need for more relevant app development for the areas reviewed (iatrogenic infection and gout respectively). Schnall and Iribarren (2015) specifically call for collaboration between medical specialists and IS developers.

In the various existing review articles on M-health, other than Varshney (2014), who identifies IT and application areas of research challenge, IS considerations are far away from their primary focus. Although there are several conference papers represented, IS journals provide only 16 M-health articles in his sample and his analysis shows that only about 11% of all M-health articles address application design, development and testing: well behind the other three areas. However, understanding what types of application development methodologies are used for M-health and their design issues is imperative to offer better understanding to M-health designers, IS researchers and industry practitioners in their further innovative developments of M-health applications. Whilst the reviews to date find no shortage of developed apps and pilot studies towards medical outcomes (Tremblay et al. 2011) these provide little contribution to research knowledge and there remains little specific contribution that can guide IS development in this field. Design Science Research (DSR) explicitly requires both a rigorous contribution to knowledge, and a development relevant to practicing stakeholders, but very few studies have been explored on this and/or applying the DSR approach in M-health are evident to date.

In the paper we used a bottom-up approach to conduct an IS focussed literature review and analysis through the use of a qualitative content analysis method (Creswell, 2012). Prior to conducting the analysis we adopt an IS design viewpoint that encompasses identifying roles of human users, and the methods used for developing and evaluating M-health artefact and design issues that are lacking in the previous M-health studies reviewed. This responds to the more recent calls for design collaboration in M-health app development that are now becoming evident. Under this approach we set two main objectives for our literature analysis. First objective is to attain better understanding on M-health research emerging themes, stakeholders and key design issues and solution technologies (hardware, software and networking). The second objective is to find the forms of methodology used, if any, to design M-health applications. In particular we aim to identify the use of DSR in M-health app development. This assessment will indicate the extent to which DSR methodologies are both used and have potential to apply in M-health app design.

The paper is structured as follows. The next section gives an overview of historical progression of M-health studies and the aspects that are of significant for a further investigation. The section after that provides methodological details followed by the findings of the study. The discussion section describes overall contributions of the study following by conclusion section in that we summarised and discussed limitations and further directions of the study.

2 STUDY BACKGROUND

2.1 M-health innovations

Although today's M-health studies really began with the invention of the smart cell phone, in 1949, AT&T invented a program called "Mobile Telephone Service", for providing health service in 100 towns and 5,000 customers in the US. However, the service experienced major technological issues as they used only three radio channels to provide only three customers at a particular time (Gruessner, 2015). Mobile technologies are now rapidly growing due to popular uptake along with emerging capacity in hardware and software as well as powerful cellular technologies, and companies like Apple and Samsung have developed features in their mobile devices (e.g. tablets, i-pads, portable computers, mobile phones and personal digital assistants-PDAs), for health services which offer potential provision of mobile health apps.

Social media allows people to be active participants in their health maintenance, and virtually connected communities are enabling people to control and self-regulate their health and wellness to make better health- and lifestyle-related decisions (Spanakis et al., 2016). Emerging technologies for consumers, responsive to individual profiles combined with public Internet realises opportunities for new types of innovations that are consumer-oriented and enable new forms of community-based provision. This has engendered innovations in the ways healthy lifestyles and well-being can be supported, while linking technologies for health, health professional and individuals in social care systems (Hwang, 2016).

2.2 Major Methodologies for M-health innovations

The proliferation of apps indicated earlier, with wearable or implantable monitors indicates the demand potential, but development is generally not research-led, and untested or ill-informed apps can be actively dangerous. Diagnostic inaccuracy, unreliable, (or reliable but invalid) measures, inappropriate treatment recommendations and data breaches or misrepresentation are just some of the recognised outcomes from improperly designed solutions (Hwang, 2016).

Many current M-health innovations are, however, designed through the use of traditional development system methodologies that encompass steps or iterations for identifying and analysing requirements, designing or implementing a system solution and testing the system within the problem domain. For instance, Radzuweit and Lechner (2014) utilised prototyping for designing a consultation service that supported effective interaction between individuals and health professionals. Milošević et al. (2011) used a basic software engineering methodology for designing an M-health application for community well-being by monitoring individuals' health conditions such as physical activity, weight and heart activity. The methodology consisted of common phases such as problem definition, (mobile) architecture design and implementation.

Many of the M-health innovations designs, however, did not evaluate the solution directly or indirectly with the target user groups. For instance, Oluwafemi et al. (2014) proposed a patient communication solution through messaging but, although the study used phases such as design, development and evaluation, the authors did not evaluate the solution with the target user patient group. This type of traditional methodology is the basic system design approach starting with requirement identification then software design and development but continues through to testing, implementation and maintenance. The Scandinavian, socio-technical and user-centred traditions have all variously argued for the continuing participation of stakeholders in this process, and designing for relevance to the realities of the operational environment, which itself may require redesign and change management.

2.3 DSR methodologies

Design Science Research (DSR) elaborates the central ideas of artifact development to embody an explicit consideration of relevance, and a rigorous method to ensure the work provides a real knowledge and practical contribution. DSR represents development, implementation, evaluation, and adaptation of artefacts for problem solving (Hevner et al. 2004) and exemplifies efforts in the design and construction of solution artefacts that might have utility for mobile applications. Because badly designed health applications can be dangerous, it is therefore important to emphasise using an appropriate design methodology for quality innovation design in the M-health sector.

DSR offers improvements over traditional methodologies in designing IS artefacts, so understanding DSR is of significance for M-health design. DSR provides methodologies that have roots in engineering and the artificial sciences (Simon, 1996). DSR "seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished" (p. 76). DSR is particularly relevant for innovative solution designs for M-health applications because it better supports designers/researchers in establishing grounding knowledge and in embedding behavioural or human aspects into the design of artifacts to solve real world problems (Schnall et al., 2014).

Hevner et al's. (2004) guidelines are intended to be supportive to designing IS artefacts in form of constructs, models, methods, and instantiations (March and Smith, 1995). M-health solutions are composed of mutable and adaptable hardware, software, and human interfaces and presents unique and challenging design problems that call for new and creative methodological ideas, to which DSR is relevant. However, although the design steps commonly used for developing M-health innovations in many IS solutions may be similar to design guidance of DSR methodologies, none of the M-health design studies reviewed previously explicitly utilised DSR. Previous literature reviews have not inventorised the design methodologies nor assessed their current status in the literature.

There is a need to assess how DSR is used in M-health app design and how DSR may better address future application design. A comprehensive content analysis on the current literature of M-health innovation design and associated issues would be of importance, not only for theoretical progression but more importantly for guiding more real-world application developments in future. Our first aim is to identify major recent work in M-health, their contributions, and the methods used by the developers.

3 Method

3.1 Procedure

The main aim of the study is to analyse recent M-health studies, to find emerging themes and to explore the use of design methodologies in developing M-health applications. For this analysis, we found it is important to focus on existing studies in two different aspects of M-health: 1) Issues of M-health development and 2) design of specific applications. Therefore two main types of sample articles are analysed to focus on these aspects. Type 1 includes articles on issues of M-health application design (e.g. key issues, study areas, factors or relationship findings studies). Type 2 includes articles on M-health application design (e.g. a particular type of solution, target user groups, and the development or evaluation methods used).

3.2 Sample articles and their sources

We used a bottom-up approach for collecting our sample articles. That is, we didn't initially select the specific outlets for selecting the sample articles but rather conducted an independent search across various databases such as Sciencedirect, NCBI, and Google scholar. Using the terms "design science (research)" and "{mobile,m} health" as initial filters on the ACM digital library, Sciencedirect and Proquest databases we identified only a handful of peer reviewed articles since 2004, with only 4 articles (conferences or journals) before 2011. We expanded the terms used (e-health and apps or applications) and the databases used to ensure better coverage of relevant articles. This also expanded the journal base beyond IS journals to relevant multidisciplinary journals. From 2011 to 2016, for type 1, we identified 22 articles and for type 2, 20 articles. The articles are from published journals (excluding conference papers and book chapters). We also excluded papers mainly concerning design of web based applications but where the relevance was only on access using mobile devices and thus we separated e-health and telemedicine from M-health studies proper. We classified the journals into two groups: top high-impact journals (such as DSS, EJIS, JAIS, MISQ, JIT, ISR, ISJ and JMIS, (ranked as top eight IS journals by ACPHIS) and lower impact or domain-specific journals (e.g. the multidisciplinary journals publishing M-health papers, such as *Journal of Medical Internet Research*, (*JMIR*), *mHealth* and *uHealth*, *Diabetes technology & therapeutics* etc). The process used to identify and select articles is shown in figure 1. Tables 2 and 3 show the pattern of results from our search and with a modal number of articles of 1, shows there is a wide range but no dominant outlets. It also indicates there is no particular upward trend in the number of publications. With small numbers this is not significant, but consistent with a nascent field of study. We now look more specifically at the content of the identified articles (Journals¹ and number of samples for type 1 and Journals² for type 2).

The five-step methodology for sample collection is as follows: step 1: keyword searching to collect list of articles from open source databases; step 2: Remove conference articles and identify that the articles are from health and IS related journals (127 articles are collected); step 3: screening through the title, abstract and keywords to classify articles into groups – apps design and issues of M-health (58 samples are collected); step 4: screening and reading through the articles for selecting care representative samples for both groups (42 articles are collected) and step 5: reading and note taking for categorising into themes of both sample groups.

3.3 Content analysis

For conducting effective content analysis deductive and inductive approaches are widely implemented. Inductive analysis is appropriate when "there are no previous studies dealing with the phenomenon or when it is fragmented" (Elo and Kyngäs, 2008). In our research, we analyse both types of articles using the inductive method, for classification and categorisation of the attributes; as suggested in Elo and

¹Nurse education today-1; *Journal of diabetes science and technology*-1; *Australasian Physical & Engineering Sciences in Medicine*-1; *Journal of medical Internet research*-3; *AIDS and Behavior*-1, *IEEE Journal on Selected Areas in Communications*-1; *Mount Sinai Journal of Medicine*-1; *PLoS medical*-1; *JMIR Human Factors*-1; *Procedia-Social and Behavioral Sciences*-1; *JMIR mHealth and uHealth*- 2; *European Respiratory Journal*-1; *Diabetes technology & therapeutics*-1; *BMC geriatrics*-1; *Procedia Technology*-1; *Diagnosis, Assessment & Disease Monitoring*-1; *Decision Support Systems*-2; *Studies in health technology and informatics*-1

² *International Journal of Eating Disorder*-1; *JMIR mhealth uhealth*-3; *Health Technologies*-1; *Journal of Medical Systems*-1; *Healthcare Information Research*-1; *JITA*-1; *Canadian Respir Journal*-1; *JCSG*-1; *Canadian Journal of Diabetes*-1; *Medical Teacher*-1; *International Journal of Cyber Society and Education*-1; *International Journal of Computer Science and Information Security*-2; *J Med Internet Res*-2; *Am J Prev Med*-1; *JMIR research protocols*-1; *IEEE Journal of Biomedical and Health Informatics*-1; *Decision Support Systems*-1

Kyngäs (2008) the result of a qualitative content analysis provides a summary of the original information and can be presented in the form of concepts and/or categories that express the investigated phenomenon.

As mentioned earlier the M-health articles are collected to gain insights on their issues, themes and whether they use any design methods related to DSR. For achieving our first objective the analysis focussed on revealing insights on issues, themes and other aspects while the second objective of the analysis focused on revealing on methodologies utilised in designing M-health. Although Elo and Kyngäs (2008) note that no exact systematic rules are appropriate for analysing data, for producing a rigorous output we followed the three phases stated by Elo and Kyngäs (2008) as guidance; these phases are preparing, organising and reporting.

In the preparing phase, the act of categorising the collected or grouped coding or headings aims to form a categorization based on related and common characteristics (Elo and Kyngäs, 2008). Elo and Kyngäs (2008) also describe the categorisation process as including the interpretation process that helps grouping of categories; the categories are used to describe the phenomenon that has been analysed. The first concern is to determine what to analyse and this naturally pertains to the research problems. As outlined above, we searched research libraries' databases and all other open database sources using 'M-health Applications', 'm-health', 'mobile applications', 'mobile health', 'remote health monitoring', 'Telemedicine', 'Medical Informatics Applications', 'e-Health', 'Healthcare', 'Mobile health monitoring', 'healthcare service', 'm-Health behaviour', 'Health seeking behaviour' terms. In the organising phase, after identifying a total of 42 articles on both types of M-health solutions, we manually went through each article to find the issues, key themes and how the design was conducted. As for the size of the sample used, although as yet there are too few for more than a descriptive exploration, we believe the number of articles is sufficient to represent the issues. In our second objective, we looked at the M-health articles for their design process description, evaluation methodologies and rigorous processes. These components relate to the explicit DSR guidelines defined by Hevner et al. (2004). Finally, for reporting purposes we used previous studies' techniques for representing findings.

4 Findings

The section describes the findings revealed in two separate analyses (details of analysis Type 1 and 2). First we briefly describe the issues emerging, and indicate some areas from recent papers not identified in the earlier studies reviewed, which had been based on an earlier sampling period. We then focus on the techniques and technologies used in more detail. Our content analysis (on type 1 samples) identified 20 areas of innovative M-health apps for stakeholders including patients, healthcare givers, doctors and healthcare professionals. We found the majority of apps were designed for patient support (such as self-care and remote monitoring) with fewer apps for healthcare professional and care-givers. The most common target audience for the apps developer are those with chronic disease or older adults. It was evident that majority of the app developers came from technological backgrounds rather than having domain specific or medical knowledge.

Varshney (2014) described four emerging themes of M-health, namely healthcare coverage, improving decision making, managing chronic conditions and providing suitable healthcare in emergencies. His survey covered the years up to 2012, and our classification extends this to a total of eight relevant themes, shown in figure 2. Our analysis on type 1 samples also found ten IS issues that are discussed in M-health studies (see figure 1). We then looked at the IT involved in the various studies. Figure 3a below shows the DSR themes for the type 2 articles analysed in our study. These themes were inductively generated from the articles themselves, and variously map to established categories from Design Science, allowing an assessment of the extent of design science techniques in this field.

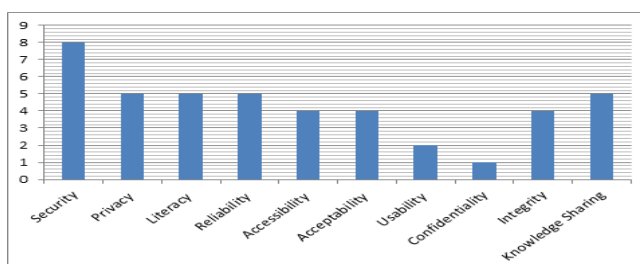


Figure 1: Issues identified in different M-health innovation studies

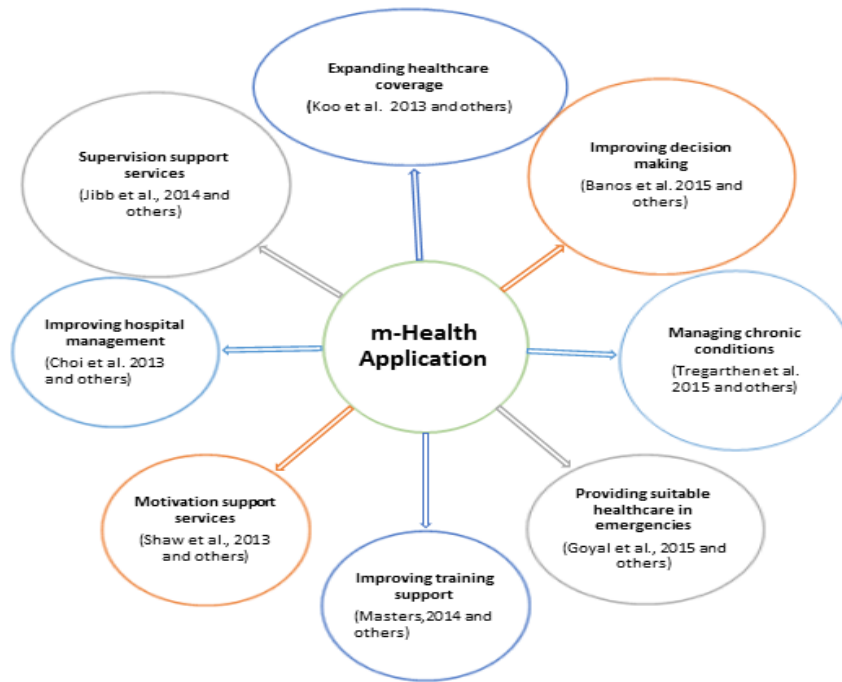


Figure 2: Eight emerging themes (innovation areas) of M-health research

Key software technique (service providers and service receiver's side)	Network technologies	Special Hardware details
PHP and MYSQL database, Java; (Oluwafemi and Olanrewaju 2014 and other studies); Unity 3D engine; (Barbosa et al. 2014); C++, Microsoft Visual C++ 2010 compiler, HTTPS; (Shaw et al. 2013); HTML code (investigated various mobile apps) (Masters, 2014); Autodesk Maya for 3D modelling, 3D Studio Max (Pulijala et al. 2015); Signal quality index (SQI) algorithm, Blowfish algorithm (Dunsmuir et al. 2014)	Wireless and GPS technology (Goyal et al. 2015); wireless sensor network (WSN) (Koo et al., 2013); Mobile Augmented Reality (MAR) Technology	Touch sensitive monitor (Choi et al. 2015 and others) Jawbone UP24 (Goyal et al., 2015) 7-lead ECG device (Huang et al., 2014), Bluetooth (Banos et al., 2015)

Table 1: Key IT choices used in M-health application design

Design Science artefacts can be constructs, models, methods, or instantiations. For each article we classified which of these was the main contribution of the research. Figure 3b shows the distribution of artefact types, which is dominated by instantiations or implementations. We also analysed the type 2 M-health articles through the 9 themes. Although most papers were not expressed using DSR terms the categories could be approximately mapped to the list in figure 3a. The 20 papers described artefact types and purposes, their descriptions related to problem definitions and design theme details informing about problem relevance, description of design steps and components, methods and approaches used, which indicated the rigour of the process and its replicability as a search process and finally the details related to the evaluation method define how this was done, as is common with system development projects. The M-health design is communicated to its target audience through the research report itself, and as applicable to its professional audiences.

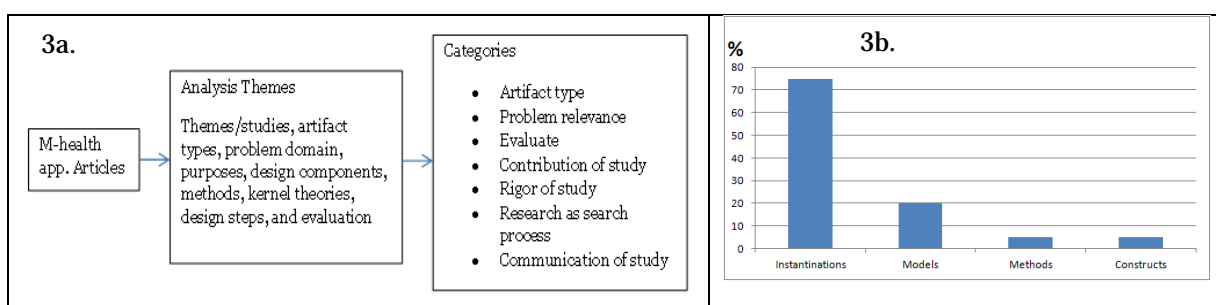


Figure 3: (a) Design science categories and themes and (b) M-health artefact types

As a norm of peer reviewed papers, the contribution of the study is a standard requirement. However, as most papers were conducted as projects, usually developing an app and describing that, few conformed fully to the requirements for design science as outlined by Gregor and Hevner (2014). The final (reporting) phase, described next, discusses how these categories were mapped to the recent literature analysed to gain insights. Table 2 (in appendix A) summarises the analysis of these articles through the themes (due to the page restriction only six samples are shown).

5 Discussion

Our analysis of the recent literature on M-health information systems has highlighted several issues not evident from previous reviews of this emerging field. Firstly, there are very few M-health studies which explicitly use design science as their approach. Most use traditional systems development, but the evaluation phase is often lacking. This is consistent with earlier findings that there was a lack of testing, and that often developers lacked the medical knowledge to be relevant to their target audience. Most papers were instantiations, with very few more theoretical artefacts being developed. Although applications had been designed, without a design science framework being used, the theoretical contribution or specification of the design is not always clear, limiting its use as a design artefact for later adaptation. On the other hand, most M-health papers followed the general practices of reporting developments to an academic audience, with most of the components being approximately mappable to DSR constructs. Those adopting user-centred approaches conform to the design principles of ensuring relevance to practical context, although evaluation of many systems by usability alone is inadequate if the application is not evaluated for relevance too.

Previous reviews of M-health studies mainly uncovered a number of emerging research themes, often from a specific medical perspective. Our work has extended previous outcomes in various ways. Firstly we have included both IS and multidisciplinary outlets, and used an up to date sample reflecting the cumulative increase in this field compared to pre-2012 literature. This has shown a larger range of themes than previously identified, with 8 fields represented in the post-2012 literature. Rather than 4 we also identified 10 issues ranging from security to knowledge sharing and a range of technologies suggesting considerable potential for further focussed IS research. The mismatch between the massive number of apps available and the relatively few studies or research-based developments further suggests research opportunities. Our analysis was also the first to focus on an IS development view of the research in M-health, which had been a limitation of previous studies, and to analyse the design and developments displayed in recent work. Our content analysis explored the emerging themes, potential design issues, key stakeholders and technologies and aimed to assess the applicability of DSR for M-health solution design, so further M-health design studies can be developed to meet and capture both attentions and requirements of technology-oriented as well as management-oriented audiences (Von Alan et al. 2004; Hevner et al. 2004). Although many studies have involved systems development, this has generally been done without a design science framework, and some gaps, particularly with respect to evaluation, kernel theories, and, as noted earlier, testing and user involvement in design are evident.

6 Conclusion

Our content analysis of the recent literature provides both an update and insights beyond previous reviews. While there is a continuing stream of research papers, this is fragmented across multidisciplinary as well as IS journals, with no dominant or central outlets. Research in this emerging field often uses IT or IS development techniques, but not always as pieces of IS research, and even more rarely using DSR. More thematic areas have emerged in recent years, and eight themes and 10 issues were identified, building on the earlier analysis by Varshney (2014). This follows Varshney's (2014) hope that his framework would continue to be extended to include more categories, and be fruitful in engendering new research problems and a cohesive agenda. Numerous research opportunities in M-health are suggested by the analysis, and within the various themes there are examples of different research approaches taken, such as prototyping and traditional lifecycle development. In our research, beyond the investigation on issues and approaches used in M-health applications, we described various ICTs – Bluetooth devices, digital camera, software such as PHP, Java, C++, MySQL, SQI, Unity 3D engine (see table 1). and networks such as MAR and cellular networks of patient's or other medical information collected by sensors, then transmitted through the use of a 3G/4G wireless network. Further to this, several wireless networks are required to work together to collect and disseminate to the findings of Rasid and Woodward (2005). Therefore, some research is also needed in creating integration of wireless solutions.

Our review of the IS developments in M-health echoes views expressed in the more medically focussed literature, which is primarily concerned with relevance to healthcare practice. They find a disconnect between the numerous apps that have been developed and the realities of medical practitioners, a familiar outcome when apps are developed without ongoing understanding of user requirements. Usability is not a proxy for relevance and applications developed without a research framework do not generally specify a knowledge contribution: in particular, those not using DSR as their approach may not cover the guidelines of Hevner et al (2004) and Gregor and Hevner (2014). The limitations of the study are, firstly, that the sample of papers, despite our search efforts, was relatively small, and the categorisations must, as with Varshney's (2014) proposal, remain less than comprehensive. The four areas identified by Varshney were, however, validated by our up-to-date sample, and as other categories are likely to emerge as the field evolves we do not stress this formulation as definitive. A second limitation is common to other systematic reviews of literature, and concerns the databases chosen and the search terms used, as well as the general limit of any data collection that is restricted by the research purposes.

References

- Baig, M. M., GholamHosseini, H., & Connolly, M. J. 2015. "Mobile healthcare applications: system design review, critical issues and challenges," *Australasian Physical & Engineering Sciences in Medicine*, 38(1), 23-38.
- Banos, O., Villalonga, C., Garcia, R., Saez, A., Damas, M., Holgado-Terriza, J. A., Rojas, I. 2015. "Design, implementation and validation of a novel open framework for agile development of mobile health applications," *Biomedical engineering online*, 14(S2), 1-20.
- Barbosa, D. N., Bassani, P. B., Mossmann, J. B., Schneider, G. T., Reategui, E., Branco, M., Nunes, M. 2014. *Mobile learning and games: experiences with mobile games development for children and teenagers undergoing oncological treatment Games for Training, Education, Health and Sports* (pp. 153-164): Springer.
- Creswell, J. W. 2012. *Educational Research: Planning, Conducting and Evaluating Quantitative*, Pearson.
- Elo, S. & Kyngäs, H. 2008. "The Qualitative Content Analysis Process," *Journal of Advanced Nursing*, 62, 107-115.
- Fiordelli M, Diviani N, Schulz PJ., 2013. "Mapping mHealth Research: A Decade of Evolution," *Journal of Medical Internet Research*, 2013;15(5):e95 DOI: 10.2196/jmir.2430
- Fiordelli, M., Diviani, N., & Schulz, P. J. 2013. "Mapping mHealth research: a decade of evolution," *Journal of Medical Internet Research*, 15(5), e95.
- Goyal, S., Morita, P., Lewis, G.F., Yu, C., Seto, E., Cafazzo, J.A. 2016. "The Systematic Design of a Behavioural Mobile Health Application for the Self-Management of Type 2 Diabetes," *Canadian Journal of Diabetes* 40 (2016) 95–104
- Gregor, S. & Hevner, A. R. 2013. "Positioning And Presenting Design Science Research For Maximum Impact," *MIS Quarterly*, 37, 337-356.
- Hevner, A. R., March, S. T., Park, J. & Ram, S. 2004. "Design Science in Information Systems Research," *MIS Quarterly*, 28(1), 75-105.
- Huang, A., Chen, C., Bian, K., Duan, X., Chen, M., Gao, H., Jiao, B. 2014. "WE-CARE: an intelligent mobile telecardiology system to enable mHealth applications," *Biomedical and Health Informatics, IEEE Journal* , 18(2), 693-702.
- Huang, A., Chen, C., Bian, K., Duan, X., Chen, M., Gao, H., Jiao, B. 2014. "WE-CARE: an intelligent mobile telecardiology system to enable mHealth applications," *Biomedical and Health Informatics, IEEE Journal of*, 18(2), 693-702.
- Hwang, K. 2016. Dangers of Defective Mobile Health Apps and Devices, URL: <https://www.verywell.com/dangers-of-defective-mobile-health-apps-and-devices-1739151>
- Jennings, L., & Gagliardi, L. 2013. "Influence of mHealth interventions on gender relations in developing countries: a systematic literature review," *International Journal for Equity in Health*, 12(1), 1-10.

- Källander, K., Tibenderana, J. K., Akpogheneta, O. J., Strachan, D. L., Hill, Z., ten Asbroek, A. H., . . . Meek, S. R. 2013. Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low-and middle-income countries: a review, *Journal of medical Internet research*, 15(1), e17.
- Koo, B., Han, K., Park, J. J. H., & Shon, T. 2013. "Design and implementation of a wireless sensor network architecture using smart mobile devices," *Telecommunication Systems*, 52(4), 2311-2320.
- Kulkarni, S., Hoffman, S., Gadisa, T., Melaku, Z., Fantahun, M., Yigzaw, M., Nash, D. 2015. "Identifying Perceived Barriers along the HIV Care Continuum Findings from Providers, Peer Educators, and Observations of Provider–Patient Interactions in Ethiopia," *Journal of the International Association of Providers of AIDS Care*, 15(4):291-300.
- Lee, J.-A., Nguyen, A. L., Berg, J., Amin, A., Bachman, M., Guo, Y., & Evangelista, L. 2014. "Attitudes and preferences on the use of mobile health technology and health games for self-management: interviews with older adults on anticoagulation therapy," *JMIR mHealth and uHealth*, 2(3). e32
- March, S. T., & Smith, G. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems*, 15(4),251-266.
- Milošević,M.,Shrove,M.T.& Jovanov,E. 2011. "Applications of Smartphone for Ubiquitous Health Monitoring and Wellbeing Management," *Journal of Information Technology and Applications*,1,7-15
- Nhavoto, J. A., & Grönlund, Å. 2014. "Mobile technologies and geographic information systems to improve health care systems: a literature review," *JMIR mHealth and uHealth*, 2(2), e21.
- Oluwafemi, A. J., & Olanrewaju, K. M. 2014. "Mobile-Health Application Software Design and Development," *International Journal of Computer Science and Information Security*, 12(7), 59.
- Payne, C. M., Knott, B. C., Mayes, H. B., Hansson, H., Himmel, M. E., Sandgren, M.,Beckham, G. T. 2015. "Fungal cellulases." *Chemical reviews*, 115(3), 1308-1448.
- Payne, H.E., Lister, C., West, J.H., Bernhardt, J.M. 2015. "Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature," *JMIR Mhealth and Uhealth*, 3(1), 1-9
- Pulijala, Y., Ma, M. and Ayoub, A. 2015. "Design and Development of Sur-Face: An Interactive Mobile App for Educating Patients Regarding Corrective Surgery of Facial Deformities," *JCSG 2015*, LNCS 9090, 26–35, 2015.
- Radzuweit, M. and Lechner, U. 2014. "Introducing tablet computers into medical practice: design of mobile apps for consultation services," *Health and Technology*,4,31–41
- Schnall, R., Rojas, M., Travers, J., Brown, W & Brkken, S. 2014. "Use of Design Science for Informing the Development of a Mobile App for Persons Living with HIV," *Proceedings of the AMIA Annual Symposium*, 1037-1045.
- Schnall, R., & Iribarren, S. J. 2015. "Review and analysis of existing mobile phone applications for health care–associated infection prevention," *American Journal of Infection Control*, 43(6), 572-576.
- Shaw, R.J., Bosworth, H.B., Hess, J.C., Silva, S.G., Lipkus, I.M., Davis, L.L., Johnson, C.M. 2013. "Development of a Theoretically Driven mHealth Text Messaging Application for Sustaining Recent Weight Loss," *JMIR M-health Uhealth*,1(1):e5) doi:10.2196/mhealth.2343
- Silva, B.M.C., Rodrigues, J.J.P.C, Diez, I.D.I.T., Lopez-Coronado, M., and Saleem, K. 2015. "Mobile-health: A review of current state in 2015," *Journal of Biomedical Informatics*, 56, 265-272.
- Simon, H. A. 1996. *The Sciences of the Artificial*, 3rd ed., MIT Press, Cambridge, MA.
- Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., . . . Gorber, S. C. 2011. "Systematic review of sedentary behaviour and health indicators in school-aged children and youth," *International Journal of Behavioral Nutrition and Physical Activity*, 8(1), 1.
- Varshney, U. 2014. "A model for improving quality of decisions in mobile health, " *Decision Support Systems*, 62, 66-77.
- Von Alan, R. H., March, S. T., Park, J., and Ram, S. 2004. "Design science in information systems research," *MIS quarterly*, 28 (1), 75-105.
- Walton, R., & DeRenzi, B. 2009. "Value-sensitive design and health care in Africa", *IEEE Transactions on Professional Communication*, 52(4), 346-358.

Appendix 1

Table 2: Findings on M-health application design studies

<i>Samples/themes</i>	<i>Artifact</i>	<i>Problem domain</i>	<i>Purposes</i>	<i>Design components</i>	<i>Methods</i>	<i>Kernel theories</i>	<i>Design steps</i>	<i>Evaluations</i>
Sample-1/expanding healthcare coverage	Instantiation	Public healthcare	To improve interaction between doctor and patients	Login, My Patients, Drugs module, Tests module, and help module	Prototyping	Theories of Healthcare practices	Problem identification, Design, deployment evaluation	Feedback of target user
Sample-2/improving training support	Method	Medical students	To develop competency development	Software Developers' Kits, Eclipse and Xcode	User centred approach	Capability development theories	Design, Development	Analytical approach
Sample-3/ Managing chronic conditions	Model	Pain management	To develop cancer pain care algorithm	Rules, algorithm design	User centred approach	Pain management strategies	Outline requirements, design and evaluation	potential effectiveness
Sample-4/ Motivation support services	Instantiation	Type 2 Diabetics management	To improve self-management using M-health apps	Synchronize blood glucose meter, Log meal or snack, activity monitoring, and weight scale	user-centred design	Health behavioural theory/ diabetic patients care	Development, feasibility, piloting, and evaluation	Feedback of providers
Sample-5/ expanding healthcare coverage	Instantiation	Public Healthcare	To design health monitoring solution	processing capabilities, memory availability, and interfacing	Experimental method	wireless sensor networks theories	Design, Analysis	Analysis of recorded response
Sample-6/improving decision making	Instantiation	Public Healthcare	To develop M-health apps considering individuals' need	Ontologies, diet, suggestion, education disease alert generation	Traditional design approach	Monitoring of patient diseases	Design, development, implementation, evaluation	Survey on patient's experiences

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